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(54) Abstract Title
Power control in mobile telecommunications systems

(57) In an UTRA-TDD communications system, a mobile terminal implements open loop power control of its transmitter power by identifying downlink time slots in which reference signals, comprising mid-amble codes, are transmitted from a base station. For power control of an uplink time slot, that one of such identified downlink slots which is closest in time to immediately before the uplink slot is selected and the reference signal energy (or power) measurement for that downlink slot is used by the mobile terminal to infer the path loss in order to control its transmit power in the uplink slot. The fact that measured mid-amble energy should exceed total noise energy by a predetermined margin in any downlink slot containing a mid-amble code is used to identify such slots. To effect this identification, the signal 80 received by the mobile is passed via an A-D converter (not shown) to a matched filter 10 in which correlation against the mid-able code is achieved by means of a shift register 110 and multipliers 130 to 144 which receive respective bit codes corresponding to the mid-amble code. The output 90 of a summator 150 passes to an energy measuring circuit 20 which computes the modulus squared to provide an energy measure for a particular path. As signal 80 is clocked through shift register 110, circuit 20 determines energy values for other paths, and an accumulator 30 provides an output 100 indicative of the total energy for all the paths for a given period of the mid-amble code. The input signal 80 is also passed directly to an energy measuring circuit 40 connected to an accumulator 50, the output of which corresponds to the noise energy summed for all paths over the given period of the mid-amble code. The output of accumulator 30 and the output from accumulator 50, weighted in unit 60, are input to a comparator 70 which gives a "1" output when a downlink slot containing a reference signal (mid-amble code) has been identified.

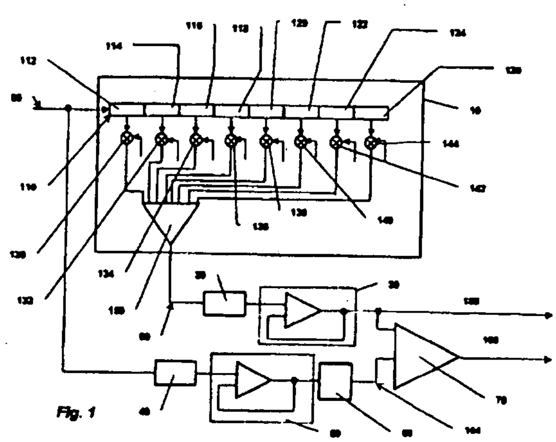

Fig. 1

At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

This print takes account of replacement documents submitted after the date of filing to enable the application to comply with the formal requirements of the Patents Rules 1995

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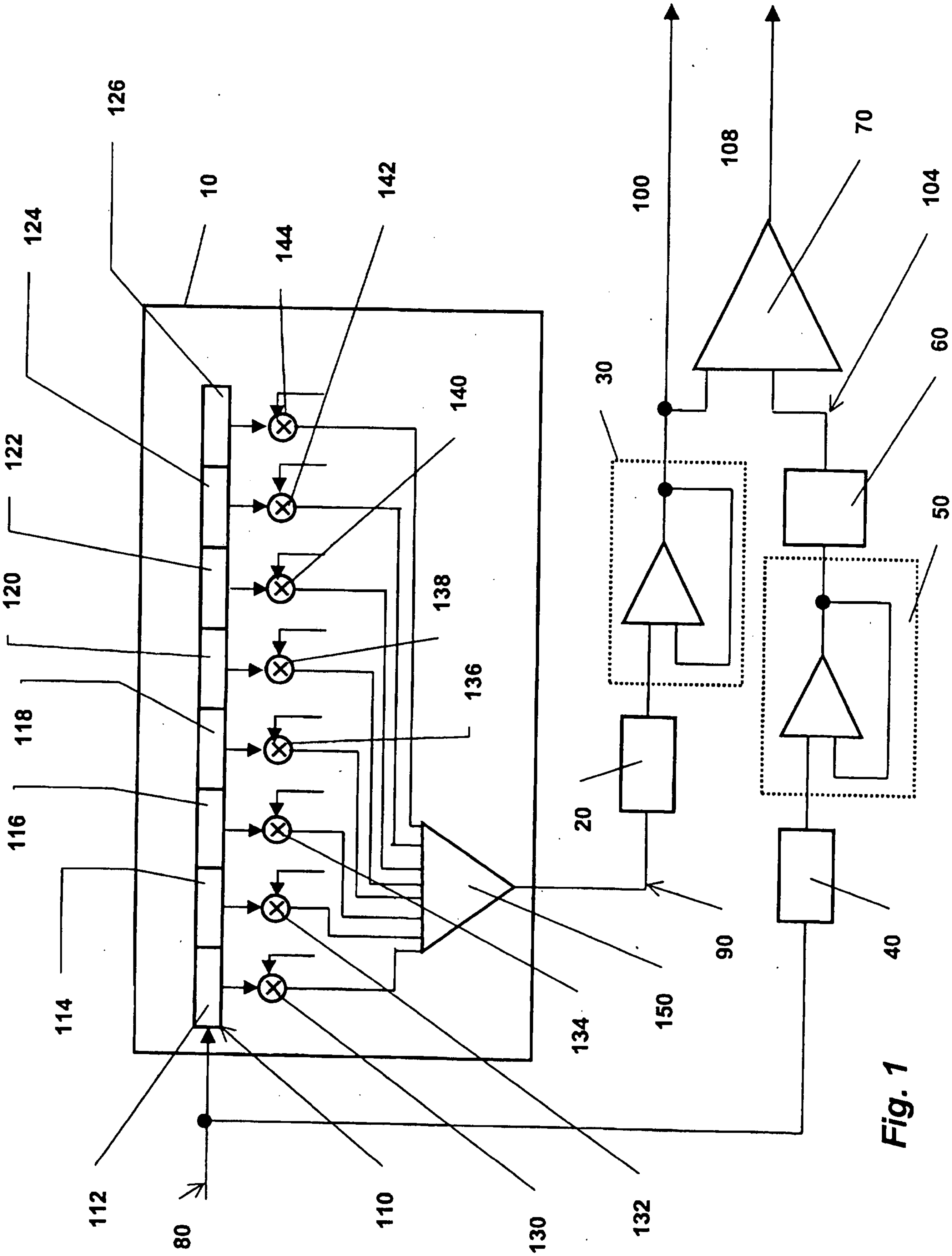
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Fig. 1

IMPROVEMENTS IN OR RELATING TO MOBILE TELECOMMUNICATIONS SYSTEMS

The present invention relates to improvements in or relating to mobile telecommunications systems, and is more particularly concerned with open loop power control for such systems.

The UMTS terrestrial radio access (UTRA) – time division duplex (TDD) system is based on a combination of code division multiple access (CDMA) and hybrid time division multiple access (TDMA) and TDD. (UMTS is an acronym for universal mobile telecommunication system as understood by persons skilled in the art.)

As the UTRA-TDD system is based on CDMA, its performance is dependent on the operation of power control, particularly, for the uplink connection, that is, the connection from a mobile terminal to a base station. Furthermore, as the system is also based on TDD, the uplink and downlink (base station to mobile terminal) connections use the same frequency and so the channel is reciprocal. Measurements of the received power on the downlink connection can be used to estimate the path loss if the base station transmit power is known at the mobile station. Therefore, if the level of interference present and the required signal-to-noise ratio of the base station are communicated to the mobile station, the mobile station can combine this information to set the correct power for reception at the base station. This procedure is known as open loop power control.

The UTRA-TDD system has a TDMA/TDD frame consisting of sixteen time slots over a period of 10ms, each time slot lasting 0.625ms. Within such a system, some time slots are permanently assigned to downlink connections for broadcast purposes, and at least one other time slot to the uplink connection for access purposes. The remaining time slots may freely

be assigned to either uplink or downlink connections as traffic requirements dictate. The time slots in which downlink connections are transmitted include reference signals of known data patterns which assist in the decoding of the transmission.

The UTRA-TDD system will usually be deployed in a cellular configuration in which the same frequency will be re-used in all cells – each cell comprising a base station and a plurality of mobile terminals within an area covered by the base station. Moreover the TDMA/TDD frames of all cells will be synchronised. However, in many cases, the inter-cell interference will be too great to permit traffic to be actively transmitted in all time slots in all cells. Accordingly, it has been proposed that the time slots be allocated to cells according to a dynamic channel assignment (DCA) algorithm to reduce inter-cell interference to acceptable levels.

As described above, a measurement of power in a downlink time slot provides an estimate of the path loss. However, if a mobile terminal is moving at relatively high speed this path loss will be rapidly changing. Thus, if, for example, a measurement is performed on time slot 0, that is, at the beginning of a frame, the path loss estimated from this measurement will be out of date by, say, time slot 8. Thus, an open loop power control scheme which performed measurements in slot 0 and used these measurements to set the transmit power in slot 8 would not control the received signal-to-noise ratio at the base station very accurately. In fact, the best performance that can be achieved will apply when the power measurement is performed in time slot N and is used to set the transmit power in time slot $N + 1$, where, for UTRA-TDD, $0 \leq N \leq 15$. In some cases, the best that can be achieved will be to perform the power measurement in time slot N and set the transmit power in time slot $N + M$ where M is made as small as possible and where, for UTRA-TDD, $0 \leq N \leq (16 - M)$.

It is therefore an object of the present invention to provide a method which allows the best performance to be achieved wherever practically possible.

In particular, within the structure of UTRA-TDD, all time slot transmissions consist of three elements, which, in time order, are - data burst 1, a reference signal and data burst 2. Because UTRA-TDD is based on CDMA, the data bursts may consist of several spread spectrum modulated components each carrying data and summed together. For the downlink, and where smart antennas are not applied, there is only one common reference signal transmitted. The reference signal comprises a fixed code against which correlations are performed for the purpose of deriving channel estimates.

Within a downlink time slot transmission, the different codes transmitting the data bursts may be intended for reception at different mobile stations. In general, in order to minimise inter-cell interference, and therefore to maximise system capacity, the powers of the individual codes are controlled independently so as to transmit only enough power to satisfy the signal-to-noise plus interference requirements at each mobile station. According to known techniques, the reference signal transmit power is set to be equal to the sum of the powers of the individual codes.

In accordance with one aspect of the present invention, there is provided a method of providing open loop power control in a hybrid TDD/TDMA mobile telecommunications system wherein reference signals of known data patterns are transmitted in downlink time slots, using reference signal energy measurements, the telecommunications system comprising at least one base station and at least one mobile terminal, the method comprising:-

a) receiving an input signal at the mobile terminal;

b) measuring and summing the energy of the reference signals in the input signal in one or more multipath components by correlation against the reference signal to obtain an overall received reference signal energy measurement;

c) measuring the total received signal energy;

d) comparing the received reference signal energy measurement with the total received signal energy measurement to obtain an indication of the presence of a reference signal;

e) selecting the reference signal position for which the time difference to the next uplink transmission from the terminal is substantially minimised; and;

f) using the corresponding reference signal energy measurement for open loop power control.

It will readily be appreciated that although reference is made to 'energy' measurements, these measurements are interchangeable wwith 'power' measurements to provide open loop power control.

It is preferred that, in all active downlink slots, that is, downlink slots in which one or more data burst codes are being transmitted, the power of the reference signals in the same time slot in adjacent frames should be held constant and the reference signal energy measurements should be used for open loop power control.

By keeping the power of the reference signals constant, and either by making this power a global constant, known to the mobile terminals or by signalling this value to the mobile terminals at suitable intervals from each base station, the mobile terminal can infer the path loss from measurements of the reference signal. However, it will be appreciated that the reference signal power need not be held constant and each time slot may have its own individual reference signal power.

For a better understanding of the present invention, reference will now be made, by way of example only, to the accompanying drawing, the single Figure of which illustrates a block diagram of a circuit for detecting the presence of a reference signal and for measuring the energy of such a signal in accordance with the present invention.

In accordance with the present invention, a mobile terminal performs measurements of reference signal energy in all time slots, other than those time slots in which it is transmitting. These time slots can be divided into three categories, namely, time slots in which no transmissions are being made either in the uplink or the downlink direction, time slots in which uplink transmissions are being made, and time slots in which downlink transmissions are being made. However, only time slots which are in the last of these categories are of interest.

In order to determine the reference signal energy for the time slots in which downlink transmissions are being made, it is necessary to identify these time slots. In the present case, the reference signals comprise mid-amble codes as they are transmitted midway through a downlink time slot. However, it will be appreciated that the reference signals can be transmitted at other positions within the time slot.

One embodiment of a circuit for determining the presence of a mid-amble code and measuring its energy is shown in Figure 1. The circuit shown in Figure 1 comprises a matched filter 10, a first energy measuring circuit 20, a first accumulator 30, a second energy measuring circuit 40, a second accumulator 50, a weighting unit 60, and a comparator 70. The matched filter 10 is connected to receive a complex baseband data input signal 80, and to provide an output signal 90. The matched filter 10 is matched to the mid-amble code for the system.

As shown, the matched filter 10 comprises a shift register 110 having eight elements 112, 114, 116, 118, 120, 122, 124, 126, eight multipliers 130, 132, 134, 136, 138, 140, 142, 144, and a summator 150. It will readily be appreciated that although the shift register is shown as having eight elements, any other suitable number may be used according to the particular application. It will, however, be noted that the number of multipliers is the same as the number of elements in the shift register and the number of elements in the code.

The baseband data input signal 80 is applied to the elements 112, 114, 116, 118, 120, 122, 124, 126 of the shift register 110 and the values stored in each element is passed to a respective one of the multipliers 130, 132, 134, 136, 138, 140, 142, 144 where they are combined with a respective bit code corresponding to the mid-amble code of the system. Output signals from the multipliers 130, 132, 134, 136, 138, 140, 142, 144 are then passed to summator 150 where they are summed and the output signal 90 is produced. Output signal 90 corresponds to the path gain for a particular path.

Output signal 90 is then passed to the first energy measuring circuit 20 where the modulus squared thereof is computed to provide an energy value for the path.

As the input signal 80 is clocked through the shift register 110, the energy values for other paths are determined in energy measuring circuit 20 and passed to the first accumulator 30 where the energy values for each path are summed with the accumulated energy values for previous paths. Accumulator 30 provides an output signal 100 which is indicative of the total energy for all the paths for a given period of the mid-amble code.

In any downlink slot containing a mid-amble code, the measured mid-amble energy as measured after correlation in the matched filter 10 should exceed the total noise energy by a predetermined margin. Thus, the presence

of a downlink mid-amble code is determined by measuring the noise energy over the period of the mid-amble code and comparing with output signal 100.

To effect this comparison, the input signal 80 is passed directly to the second energy measuring circuit 40 where the energy value in each path is determined as before. The accumulations are arranged to continue over the period of the mid-amble code as described above in accumulator 50 to provide the noise energy corresponding to all the path. However, as several path positions are added together, the noise energy measurement must be weighted accordingly. In UTRA-TDD, the period over which paths are measured is n chips, for example, $n = 57$. Path energy measurements for all n positions will multiply the noise energy or power level by n.

Alternatively, the weighting factor can be reduced if path thresholding is performed. This can be done by taking longer term averages over mid-amble code measurements for those time slots in which the downlink mid-amble code is known to be transmitted, such as, the time slot known to contain the common control physical channel (CCPCH). In this way, the exact chip positions of known mid-amble code paths, assuming that the mid-amble code is transmitted, can be identified for the entire frame. If, for example, a maximum of eight paths are taken to be non-zero, then the noise energy for comparison will be weighted only by 8 rather than by n.

The energy values for all paths in the period of the mid-amble code are passed to weighting unit 60 so that the noise energy values can have the appropriate weighting applied as described above prior to providing output signal 104 as shown.

Output signal 104 is then passed to the comparator 70. Output signal 100 from the first accumulator 30 is also passed to the comparator 70. Comparator 70 compares the two signals 100, 104 and provides an output signal 108 which is indicative of that comparison. Output signal 108 from

the comparator 70 either comprises a '0' or a '1'. In the former case, this means that the difference between signal 100 and signal 104 does not exceed the predetermined margin, as defined by the value incorporated into the signal by weighting unit 60, and therefore the energy values measured relate to noise as no mid-amble code is present. In the latter case, this means that the difference between signal 100 and signal 104 exceeds the predetermined margin and a mid-amble code has been detected.

Thus, in accordance with the present invention described above, it is possible to identify downlink time slots containing mid-amble codes. The measurements of the downlink energy values can be further improved by subtracting the noise measurements in order to obtain unbiased measurements of the signal only component (not shown). Having identified the downlink slots containing mid-amble codes, it remains only to select the most appropriate mid-amble code for open loop power control. This consists of selecting the mid-amble code, which is closest in time to immediately before the uplink time slot. Where available the immediately preceding time slot would be used. However, if the mobile terminal receiver is implemented in such a way that there is some latency in the measurement of the time slot energy, for example, one time slot, then the minimum gap will clearly increase (to one time slot in this specific example) for this latency.

It will be appreciated that the circuit described above operates in the digital domain, the complex baseband input signal 80 being in digital form after being processed by an analogue-to-digital converter (ADC) (not shown).

Automatic gain control (AGC) may be applied to set the levels of the signals passing into the ADC. However, it will be noted that the analogue AGC will operate on the composite input signal rather than any specific component such as a mid-amble.

As described above, the mobile terminal makes autonomous selection of the downlink time slots to use for open loop power control. However, the process cannot compensate for unfortuitous assignments of the time slots by the base station. Accordingly, also in accordance with the present invention, the time slots in the base station can be assigned in such a way as to maximise the benefits of energy measurements for open loop power control. There are several approaches which can be implemented to achieve an optimisation of these measurements.

In one embodiment, a mid-amble code is transmitted in every time slot which has been assigned to downlink operation in that base station, whether data bursts are being transmitted in that time slot or not. This increases the number of downlink time slots containing mid-amble code transmissions.

In another embodiment, a mid-amble code is transmitted in every time slot, which has been assigned to downlink operation, in every base station operating within the system.

A further embodiment utilises the fact that whenever a call is set up in UTRA-TDD, at least one resource unit must be allocated in both the uplink and the downlink. A resource unit is defined as a combination of a time slot and a spread spectrum code. In this embodiment, the call set up procedure in the base station is arranged to assign downlink resource unit(s) in a time slot as close in time to immediately before the time slot assigned for the uplink resource unit(s) as possible. Where the required number of resource units in either or both directions dictates that more than one time slot be assigned for that direction, these time slots should be assigned in such a way as to maximise the benefit for open loop power control. Except where unavoidable, consecutive time slots should not be assigned to uplink operation since the power setting for the later time slots will be further from

that required than the power setting for the first time slots. In most cases, it should be possible to satisfy the condition since asymmetrical operation will most often be required to provide greater downlink than uplink data rates.

Additionally, the operation of the dynamic channel assignment (DCA) can be optimised. Optimum operation arises when the uplink time slots for a given base station are close in time following the downlink time slots for that same base station. By constraining the DCA algorithm to allocate contiguous blocks of time slots to each base station, the operation can be optimised. Moreover, the allocation for each base station should arrange for the first time slot to be dedicated to downlink operation and the last to uplink with the intermediate time slots assigned to optimise the operation of open loop power control but consistently with the long to medium term balance between uplink and downlink traffic loads.

CLAIMS:

1. A method of providing open loop power control in a hybrid TDD/TDMA mobile telecommunications system wherein reference signals of known data patterns are transmitted in downlink time slots, using reference signal energy measurements, the telecommunications system comprising at least one base station and at least one mobile terminal, the method comprising:-

a) receiving an input signal at the mobile terminal;

b) measuring and summing the energy of the reference signals in the input signal in one or more multipath components by correlation against the reference signal to obtain an overall received reference signal energy measurement;

c) measuring the total received signal energy;

d) comparing the received reference signal energy measurement with the total received signal energy measurement to obtain an indication of the presence of a reference signal;

e) selecting the reference signal position for which the time difference to the next uplink transmission from the terminal is substantially minimised; and;

f) using the corresponding reference signal energy measurement for open loop power control.

2. A method according to claim 1, further comprising the step of:-

g) assigning time slots in the base station for maximising measurements for open loop power control.

3. A method according to claim 2, wherein step g) comprises transmitting a reference signal in every time slot.

4. A method according to claim 3, further comprising transmitting a reference signal in every time slot for every base station.

5. A method according to claim 2, wherein step g) comprises allocating at least one resource unit in a downlink connection in a time slot as close in time to immediately before a time slot allocated for at least one resource unit in an uplink connection.

INVESTOR IN PEOPLE

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Claims searched: 1 to 5
Examiner: M J Billing
Date of search: 25 October 1999

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.Q): H4L LDG, LECX.

Int Cl (Ed.6): H03G 3/20, 3/30; H04B 7/005; H04Q 7/32.

Other: ONLINE - EPODOC, WPI.

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
A	GB2268365A	(ROKE MANOR) - page 7 line 1 to page 8 line 17	1
A	EP0668664A1	(MATSUSHITA) - Abstract	1
A	US5631921	(INTERDIGITAL) - Figs.3,5	1

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